APPENDIX I

Adjustment of the Solar Unit

First, make certain that the transit itself is in good order. Before making any adjustments of the solar unit, determine that:

(1) The solar telescope revolves smoothly in its collar bearings, neither too tightly nor too loosely.

(2) There is free and smooth motion to the latitude and declination arcs.

(3) The clamps are positive, and the tangent motions smooth.

(4) The eyepiece is carefully focused upon the crosswires.

(5) The objective is carefully focused upon a distant object, then secured in this position.

Field Tests

If the general adjustments, accomplished as hereinafter described, have not been disturbed appreciably, *there are only three field tests preliminary to checking the solar unit for orientation.* Two of these are made by the prime vertical method, more fully described under that heading; the third is the noon observation.

(1) To ascertain whether the line of collimation of the solar telescope (or polar axis) is truly parallel to the vertical plane of the transit telescope when the solar is set and clamped in the latitude of the station. Any difference here *is a constant,* i.e., any discrepancy to the right or to the left should remain the same in all orientation, both a.m. and p.m.

Select a suitable sighting point, then in order to find its reflected image, determine the vertical angle counting from the H.I. or reflector; compute the setting for a north declination on the value: $\sin \delta = \sin \phi \sin v$.

Start with the main telescope on the sighting point, plate reading at zero, reflector in the direction of the sighting point; the solar telescope clamped in the latitude of the station; a north declination set on the above value.

On the first check, turn the transit 90°, and turn the solar telescope in hour angle to pick up the image of the sighting point. It is usually helpful to shade the reflector so as to protect it from all light excepting those rays coming from the direction of the sighting point. Next, set the central equatorial wire on the image of the sighting point by movement of the declination tangent motion. This brings the solar unit in a position for beginning the reversals, alternately at 90° to the right and left of the line from the transit station to the sighting point.

In making the reversals, each on the exact plate setting of 90°, correct as necessary, half on the declination tangent motion, half on the lower tangent motion of the transit. When good in both positions, set back to zero on the horizontal plate. Observe the sighting point; if good in the main telescope, the adjustment for parallelism in this latitude is good. If the main telescope is to one side of the sighting point, note which side, and the amount; that will be the discrepancy in parallelism for the latitude of the station.

Ordinarily no change in the adjustment should be made at this stage, nor until it has been demonstrated that there is a consistent discrepancy that can be improved by a "touch up" adjustment. Before doing that analyze the results given by the prime vertical method for parallelism both in this position and in zero latitude to ascertain which of the two points of adjustment can be improved.

(2) To ascertain the index error of the declination arc, suitable for the date, and for the range of the sun's declination in that immediate

period. In this test the solar telescope is set and clamped in zero latitude. The declination arc is set at or near the desired declination.

If the sighting point is in the horizon, the angle to be turned on the plates for the successive reversals will be $90° \pm \delta$; plus for north declination; minus for south declination. If the sighting point is above the horizon, the value of the angle to be turned on the plates should be determined by the equation: $\cos A = \frac{\sin \delta}{\cos v}$, "A" being the horizontal angle counting from the sighting point. The equation gives the right *supplemental value* for the plate angles for the same north or south declination value; over 90° for north declination; less than 90° for south declination.

Start with the main telescope on the sighting point, plate reading at zero, reflector in the direction of the sighting point. On the first check, turn the solar telescope in hour angle, and pick up the sighting point by the tangent motion of the declination arc. On the subsequent reversals, each on the exact plate setting as determined by the equation, correct as necessary, half on the declination tangent motion, half on the lower tangent motion of the transit. When the sighting point is in good position on the reversals, without having to change the tangent motions as described, read the declination arc carefully. The difference between this reading and the value of the declination that was used in the equation is the exact index error for that position in declination; this gives the index error to employ for that date or period.

(3) To ascertain the *instrumental latitude* of the station. The instrumental latitude is the one observed by the solar unit at apparent noon. It may agree with, or it may be slightly more or less than the true latitude. The instrumental latitude is the one to employ in solar orientation, as this value disposes of any possible discrepancy between exact zero setting for latitude (index error at horizontal) and correct reading for the station.

With the instrument carefully levelled and set in the meridian, and having carefully set the declination arc for the sun's noon declination for that date, with refraction duly added to a north declination, or subtracted from a south declination, and with the index error of the declination arc determined as above explained (2), duly applied to the declination as calculated, bring in the sun at meridian passage with the tangent motion of the latitude arc. The reading of the latitude arc will then be the proper instrumental latitude. This is tested daily in regular field practice.

Orientation

The solar unit is now ready for p.m. and a.m. tests for orientation, by comparison with a carefully determined meridian. Any discrepancy in (1) will be a constant, as already noted. A discrepancy in either (2) or (3) will result in a variable orientation. (Table 22, Standard Field Tables).

If the field tests (1), (2), and (3) have been carried through successfully, the solar unit should give satisfactory orientation within the Manual tolerance (1′30″ during the usual hours), without going through the general adjustments.

The tests for orientation should duplicate actual line practice on the survey. Care in levelling, and close setting of the arcs to the nearest half-minute; everything counts just as in making an altitude observation for azimuth, recalling that the variables in the latter will also be appreciable and can be brought within small limits only by close attention to every element of the observation.

The general adjustments are designed for the instrument assembly in the beginning, and after repairs have been made, or in remounting a solar unit if it has been removed. These give attention to the correct relation of all working parts, good for any latitude. The general tests and adjustments are also made after the return of an instrument at the end of a long season; after cleaning and lubrication; and to ascertain if repairs are required. Again, after repairs have been made, to see that an instrument is ready for field assignment.

Any large discrepancies in the field test (1), (2), and (3), or in the orientation trials, will demonstrate that something is fundamentally wrong in the condition of the solar unit, or in the general adjustment. Ordinarily this will be unusual, indicating that some important detail has escaped attention. The smaller discrepancies, or residuals, are best taken care of by close attention to the performance, day after day in the tests on the camp meridian, and in the observations that should be made frequently on the lines of the survey to verify the instrumental performance.

A uniform discrepancy in orientation, i.e., always holding about the same amount to the right or left of the meridian, may be traced only to field test (1), to be treated as an index error, or to be corrected by careful touch up adjustment when fully demonstrated.

The variables are more difficult to analyze. Those traceable to either (2) or (3) may be due to poor fitting of the clamps or tangent motions; back lash in the tangent screws; opposing springs not in good order; or a weaving in the tangent motions; these are mechanical difficulties. Another mechanical difficulty, not at all unusual on worn instruments, which will be manifest in variable orientation, may be traced directly to poor fitting of the collar bearings, too snug in a portion of the turn, too loose in places, or not truly round. All other tests may appear to be good, but if the outside equatorial wires may not be spaced equally from the true line of collimation it will establish a residual that is disturbing until fully identified by performance.

Detail of the Adjustments

The general adjustments of the solar unit should be considered in the following order:

(1) The equatorial wires must be made parallel to the axis of the reflector.

(2) The line of sight of the solar telescope must lie in its true turning axis.

(3) The polar axis, or line of sight of the solar telescope, must be normal to the axis of the latitude arc, describe a true vertical plane when turned in latitude, and this plane must be parallel to the vertical plane of the transit.

(4) The latitude arc should read zero when the solar telescope is horizontal, and should be tested for reading true latitude of station.

(5) The declination arc should be tested for reading the true declination of the sun, plus the refraction in polar distance, in all positions.

(6) The hour circle should read the sun's apparent time.

Additionally, tests are required to ascertain:

(7) If the collar bearings are free from inequality or roughness that would cause a displacement in the turning in hour angle from 6 a.m. to 6 p.m., i.e., truly round.

(8) If there is appreciable inequality in the spacing of the equatorial wires.

The above may be termed performance requirements and tests, as distinguished from the maker's adjustments which are designed to accomplish the correct construction and assembly. There are several methods of approach to the general adjustments, all with regard to the same geometric problem wherein each step is intended to bring one element into appropriate relationship with the other parts.

The Solar Diagram

The general adjustments, and preliminary tests, may be accomplished most readily with the help of the solar diagram, dimensioned for the particular instrument or instruments of that model. The diagram is mounted by means of a board, similar to a plane-table board but held vertically by a bracket, on a light tripod, placed at a measured distance from the instrument, and adjustable to the same H.I. The diagram has the appearance shown below for the arrangement of the lines and the lettering. The letters read normally when viewed through the solar telescope with its inverting eyepiece, and when receiving reflected light rays in certain positions of the tests. See Figure 92. To be placed in pocket.

The measured base is required only for the tests (7) and (8); it may be used also for a check of the transit stadia-wire interval; the same diagram is correct for any model in these particular tests. The base measurement from the vertical axis of the transit to the face of the drawing board is 2.50 chains (165 feet).

The diagram may be placed at any distance for the remaining tests, the conditions being to secure the same H.I., good light, and sharp images, including the reading of the letters, which will appear normal, and will identify the line that is to be used in each test. The several offset lines are placed to conform with the dimensions of one standard model.

The board is to be oriented to face the transit, carefully set to exact right angle with the line of sight, vertical, and moved into the exact H.I. of the transit. The lower horizontal lines then indicate the H.I. of the solar telescope. The "D" and "R" vertical lines show the offset of the solar telescope when in direct and reversed positions measured from the vertical axis of the transit. The lower vertical lines are for testing the declination arc at 0° and at 15° each for north and south declinations. The "X" lines are for testing the parallelism of the telescopes when the solar is set and clamped at latitude 40°.

(1) *The equatorial wires, for parallel to axis of reflector.* With the solar telescope clamped at 0° latitude, 0° in declination, and the transit oriented 90° from the line to the target, pick up the reflected image of the main vertical line. Use the transit tangent motion to bring the central equatorial wire onto the vertical line. Then turn the solar telescope in hour angle. The equatorial wire should follow the central intersection across the field. If not in good adjustment, the solar cross-wire assembly, or reticle, requires a slight rotation to bring it into good position.

The test may be made on the sun, as follows: set up the instrument as in a regular solar observation, setting off the latitude, declination and apparent time; bring the sun's image accurately between the equatorial wires by orienting the transit, in which position the instrument should be clamped. Turn the solar telescope in hour angle, causing the sun's image to travel across the field from side to side. If the image follows the equatorial wires accurately the latter are parallel to the axis of the reflector as required.

If the image departs materially from the equatorial wires, the capstan screws which hold the reticle should be loosened, and the reticle rotated until the equatorial wires are made to agree with the path of the image across the field; then return each capstan to a proper seat.

(2) *Collimation.* With the solar telescope clamped at 0° latitude, make a direct sighting on the solar diagram, using the transit tangent motion to set on the vertical line; the latitude tangent motion to set on the horizontal line. Turn the solar telescope 12 hours in hour angle; the displacement, if any, on the center intersection, is *double* the error in collimation, in both directions, for the equatorial wires, and for the time wire.

The same test may be made by sighting on a distant point: set the line of sight on a distant point and clamp the instrument. Revolve the solar telescope 12 hours in hour angle. If the line of sight remains fixed on the point it agrees with the turning axis as required. If after revolution, the line of sight appears to be above or below, or to the right or left of the point, one-half of each difference should be taken up with the capstan screws. The test should be repeated. This test and adjustment is similar to collimating the telescope of the Wye level.

As the eyepiece of the solar telescope gives an inverted image, the *direction* for the movement of the reticle to correct for collimation is *apparently to reduce* the error, i.e., if there is appreciable displacement, turn the capstan screws so as to move the reticle in the direction towards the image of the sighting point, both vertical and horizontal. The correction is for *only half the amount* of the displacement. Be very careful not to over-adjust, i.e., not to pass the point of perfect adjustment. Exercise the same precautions as in adjusting the transit telescope for collimation.

(7) and (8) *Collar bearings, and spacing of the equatorial* wires. The next step is to test the spacing of the equatorial wires. These should fit the outside line of the inner circle, spaced on a radius of 15′45″, which is the sun's semidiameter at the July 1 date. Check carefully for equality of spacing on the two sides.

There is no way to correct an inequality except by the maker. If there is an appreciable inequality, the collimation test should be by the reversal of one outside equatorial wire into the position of the other, rather than on the central point of intersection.

Carefully turn in hour angle, pausing at each hour interval, to check the rotation of the solar telescope in its collar bearings. Any roughness or inequalities will be manifest in the direct sighting on the circle, i.e. the equatorial wires will appear to jump or to be displaced in relation to the circle. If there is appreciable displacement at any point, note the place on the hour circle. There will be a corresponding displacement, or variable, in the orientation tests on the meridian at the same position in hour angle. Irregularities in the collar bearings cannot be corrected in the field.

(3) *The polar axis.* Several steps are combined in this adjustment. The line of collimation should be normal to the latitude axis; the latter should be horizontal; and the plane of the solar line of collimation when moved in latitude should be parallel to the vertical plane of the transit. This makes for general adjustment in any latitude. For just one latitude or area it is only necessary that the line of collimation (as a line, called the *polar axis*) be made parallel to the vertical plane of the transit. The field test (1), preliminary to the test for orientation, heretofore described, takes care of that.

Make a direct sighting of the solar telescope on the D line of the target, first setting the transit telescope on the main vertical line. If the solar telescope points to one side of the D line, note the amount and whether to the right or to the left. Turn the transit 180° and repeat, sighting with the solar telescope in the reversed position. Note the amount that the pointing is to one side of the R line, and whether to the right or to the left. The two pointings now require analysis. For illustration, assume pointings as indicated by diagram "a", Figure 93. To be placed in pocket.

NOTE. First, the diagram projections are in true relation. With the inverting eye-piece (image inverted) the right and left appear reversed, and the image is upside down; Second, if the line of sight is not normal to the latitude axis, the line will describe a *cone* in the reversal.

The short dash line is the normal to the latitude axis; the full line shows the assumed pointings.

Adjust first on the base plate at the foot post that controls the pointing at horizontal sighting; make the correction to the position where the sighting will conform to the full line in diagram "b".

In the projection, the latitude axis will be normal to the vertical plane of the transit (although not necessarily horizontal). The pointings should be symmetrical with respect to the D and R lines.

Adjust second at one end of the frame that supports the solar telescope. Make the correction to bring the pointing exactly to the D and R lines, as shown in diagram "c". This brings the line of sight of the solar telescope into normal with the latitude axis.

In using the solar diagram, the adjustment that is required *to bring the latitude axis into horizontal* must be preceded by the test for the zero position of the declination arc, but when that has been accomplished (the declination vernier remaining clamped in that position) then set and clamp the solar telescope in latitude 40°. From this point on, the steps are as previously described for the primary field test (1) to ascertain if the line of collimation of the solar telescope, when set and clamped in the latitude of the station, is parallel to the vertical plane of the transit.

Make the test on the X lines, either a.m. or p.m. position; *reflected light rays* as in regular solar orientation; all clamps set; transit turned 90° from the main line of sight. This setting will be either 6 a.m. or 6 p.m. in hour angle. The adjustment should check in both a.m. and p.m. positions, which accomplishes a reversal of the horizontal axis. The slant of one line of the X represents the direction of the sun's movement at sunrise or sunset, zero declination, 40° latitude. The reflected image of the second line of the X will appear to be horizontal. The intersection is in the same H.I. as the reflector in the line of the polar axis.

When taking the sight, the center equatorial wire will be on, or parallel to, one line of the X, and will follow that line, or continue to be parallel to it, when the solar telescope is turned in hour angle.

The adjustment is good when the center equatorial wire is on the line of the X. If adjustment is required, bring the center equatorial wire to the line of the X; adjust on the base plate at the foot post that controls the position of the latitude axis for true horizontal.

The adjustments at the foot posts on the base plate of the solar unit should now be fully accomplished, or completed except for the slightest "touch up" if and when the need becomes demonstrated by performance in orientation, and then only to secure final accuracy in the position of the polar axis for parallelism with the vertical plane of the transit.

Note also, that the adjustments on the foot posts should be in final position, or nearly so, before making the test (4) for the index error, if any, in the setting of the *latitude vernier*.

The mechanical construction at the points of contact of the base frame of the solar unit with the *inner* capstans or hexagon nuts at the foot posts is designed to accommodate an adjustment *without straining* the base frame, but care is necessary not to place too much pressure on the points of contact while making adjustments. A strain here will cause difficulty in coming into good position, or a jump in position when the strain is relieved. The safest plan is to ease off the pressure at the point or points that must be relieved in order to make the adjustment, also a slight easing off at the other point or points (including the one at the 90° angle); follow with the adjustment turns; then re-seat with equal pressure at each point.

The statement of the adjustments of the polar axis is intended to show the successive steps that are appropriate when the whole unit requires examination and testing. Later, an explanation will be given for the more rigid test of the polar axis by the prime vertical method. If a residual error is then present, the latter test will show which point of adjustment on the foot posts will control the improvement.

While the statement here may seem involved, the steps are simple enough if taken in proper order. A demonstration by some one experienced in solar transit work will be an aid to those who may need that assistance. The way to accuracy in solar transit orientation, as in all observations for azimuth, is to give close attention to every essential detail.

The latitude axis may be adjusted to horizontal as described in the next paragraph, striding level method, including also the other steps to bring the polar axis into good position, if the solar diagram is not available. Note that the striding level method for this and the next adjustment is applicable only to model A.

Carefully level the transit and then sight the main telescope to a distant point and clamp the instrument; sight toward the same point with the solar telescope, and place the striding level on the latitude axis. The striding level should be reversed to see if there is any error in the level itself, and if so take the mean position for the true indication of the level.

If the latitude axis is not horizontal it may be made so by adjusting the capstan nuts on the base frame.

If the line of sight of the solar telescope is not parallel to that of the main telescope it may be made parallel by means of the capstan nuts on the base frame of the solar. Next, turn the transit 180° in azimuth and reverse both telescopes so as to sight again to the same distant object, setting the main telescope upon the object. If the solar telescope does not again sight upon the distant object, one-half the error is due to its line of sight's not being at right angles to the axis of the latitude arc. Take up half of the amount of the error by means of the capstan nuts at one end of the solar telescope, and take up half of the error by correcting the capstan nuts on the base frame of the solar. The line of sight should now be normal to the axis of the latitude arc, should describe a vertical plane when turning on said axis, and this should be parallel to the vertical plane of the transit. The tests should be carefully repeated until the adjustments are perfected.

The several steps for the adjustment of the polar axis may be accomplished, and rigidly checked by the prime vertical method, hereinafter described more fully.

(4) *The latitude vernier-Solar diagram.* With the transit carefully leveled, make a direct sighting with the solar telescope; use the latitude tangent motion to bring the central equatorial wire on the lower horizontal lines (hour angle at noon). The reading of the vernier will indicate the index error in zero latitude.

As a rule it is better not to change the vernier setting if the fitting is good and only a small difference exists. The primary field test (3) is made to secure an *instrumental latitude* at the station. Ordinarily that will agree with the true latitude ± the index error at 0°, or check this very closely. A discrepancy will appear in case there should be a slight eccentricity in the mounting of the latitude arc on its frame, i.e., there will be a slight variable in the index error between 0° and the part of the arc as from 30° to 50°.

The test may be made with the striding level as follows: Carefully level the transit, clamp the latitude arc at zero, and place the striding level in position on the solar telescope. The striding level should be reversed to see if there is any error in the level itself, and if so take the mean position for the true indication of the level. If the telescope is not horizontal it may be made so by means of the tangent motion of the latitude arc. When it has been made truly horizontal the reading will indicate the index error of the vernier of the latitude arc. The vernier may be shifted to read zero, or the difference from zero may be carried as an index error.

Without the solar diagram or striding level, the test may be made by first ascertaining a sighting point (or line) in the true horizontal plane of the solar telescope.

(5) *The declination vernier-Solar diagram.* Set and clamp at 0° latitude, and the declination at or near 0°. Set the main telescope on the long vertical line, then turn the transit 90° to the left, and the solar in hour angle to 6 p.m. Pick up the image of the central short vertical line, p.m. position; set the central equatorial wire exactly on that line by the declination tangent motion. Now reverse the transit, oriented 90° to the right of the solar diagram; turn the solar telescope 12 hours in hour angle to the 6 a.m. position. Pick up the image of the central short vertical line, a.m. position; note the central equatorial wire, and if not in coincidence make the correction *half* with the declination tangent motion, *half* with the lower tangent motion of the transit. Repeat the reversals, and the half-and-half corrections until there is coincidence in both a.m. and p.m. positions. The reading of the declination arc will give *the index error, if any, in the setting of the vernier in zero declination.* If the discrepancy is small, and the vernier well fitted, it is usually better not to disturb the adjustment.

On the solar transit constructed between 1914 and 1945 (Model A) the declination arc and vernier are both movable. The arc should not be moved unless necessary to correct for radius, or to correct for concentric position with the axis of the reflector. The vernier may be shifted as necessary to correct for index error.

On the solar transit constructed between 1937 and 1945 (Model B) the declination arc is fixed in position. The vernier is held in position by two small screws; it may be shifted if necessary.

On the model constructed since 1946 (Model C) the declination arc is permanently seated at proper radius, and proper spacing. It is not intended that this relationship will be disturbed by field adjustment. The vernier is graduated on the declination-vernier arm. The vernier adjustment is controlled at the reflector axis, where the declination-vernier arm is locked in position by three setscrews. The setting is carefully made at the time of construction. It should rarely require attention except at the time of repair by the maker.

When setting the vernier in zero position, a test is made to bring the reflector into an exact 45° with the line of collimation of the solar telescope. The reflector and the tangent-clamp-arm are left clamped in that position.

The first step in making the adjustment is to loosen the three hold-down screws, just enough to allow the declination-vernier arm to be shifted. The reflector position is not disturbed. Next, remove the "dummy" screw that is placed about midpoint of the arm, and in its place insert the special adjusting post (the latter will be found inserted, for safe keeping, near the top of the right standard of the transit). When in position the end of the post projects into a hole in the tangent-clamp-arm. There are two opposing capstan screws in the tangent-clamp-arm which are to be brought into play against the adjusting post.

The parts are now in position for an exact setting of the vernier to zero reading on the declination arc. Two capstan pins are used in opposing movement to accomplish the exact adjustment.

After adjustment, tighten the three hold-down screws at the reflector axis. Back off the two opposing capstan screws. Remove the special adjusting post. Replace the "dummy" screw. Replace the adjusting post for safe keeping. Tighten the two capstan adjusting screws to avoid loss.

Repeat the original test to make sure that the declination clamp held properly during test and that the reflector position was not disturbed from any cause.

The next step is to check the reading at 15° north declination. Proceed in the same manner as above, except to make the turns 105° to the left and right of the solar diagram, and use the N lines in the p.m. and a.m. positions. Record the reading when the reversals indicate true position 15° north declination.

Check again on 15° south declination. The turns are 75° for the S lines.

The arc and vernier are *well mounted* when the index error, if any, runs along the same, or nearly the same in three positions. An appreciable variable will indicate an inaccuracy in the mounting of the declination arc, either in the setting for radius or an element of eccentricity, or both.

The field test (2), preliminary to the test for orientation, heretofore described, will ascertain the index correction in any position of the arc. In field practice it should be determined for the period when the instrument is being used.

A careful analysis of the variables in orientation in actual performance of the instrument during the early a.m. and late p.m. hours will show if the index correction for the declination reading is about right, or if it can be improved slightly. Those periods are best for that check because any slight discrepancy in the reading of the latitude arc, which would be apparent during the 6 or 8 hours of the middle portion of the day, disappears in the early a.m. and late p.m. The check should not be made when too close to sunrise or sunset as the refractions then become large and more or less uncertain.

(6) *The hour circle-Solar diagram.* This adjustment may be made at any stage of the tests after the completion of (1). Make a direct sighting. Bring the time cross wire into coincidence with the long vertical line. In that position the circle should read 12 hours. There is a set screw which holds the graduated circle in position; the circle can be shifted as needed.

Without the solar diagram, make an observation for the meridian passage of the sun. A few minutes before apparent noon set the instrument in the meridian, elevated to the sun's altitude. Set your watch to read 12 o'clock as the sun's center crosses the vertical wire of the main telescope. At any convenient time thereafter set off the proper readings on the latitude and declination arcs, and with the instrument in the meridian, bring the sun's image to the center of the field of the solar telescope and observe the watch time. If the reading of the hour circle agrees with the watch it is in adjustment; if not, it may be made to read apparent time by loosening the set screw which holds the hour circle in position, shifting the circle until the reading agrees with the watch, care being taken not to move the telescope in hour angle until after the set screw is again seated. The test may then be repeated.

The Prime Vertical Method

A complete adjustment may be accomplished by the prime vertical method. These tests are made by using a distant sighting point, and do not require the solar diagram or the striding levels. Some of the tests are by direct sighting; the remainder are in the positions where the arcs are clamped as in normal orientation, light rays reflected.

The plan is based on the conception of using the solar unit for an observation upon a star when in or passing the prime vertical, equal altitude method, permitting all necessary reversals. A suitable sighting point serves for the star position. It is intended especially for use when duplicating field conditions, and mainly for the touch up adjustments, rather than for running through the general adjustments.

The conditions for the sighting point are that it may give a sharp point that can be seen clearly as a reflected image. If it is a long distance away it may be used as a point in all of the sightings, but if substantially less than one-half mile an allowance should be made for the instrumental offsets as presented in the solar diagram method. A sky-line point may be used under many field conditions, as the station will frequently be remote from a church spire, flag pole, water tower, and such ideal sighting points. If no suitable point can be picked up from the instrument station, a piece of white paper may be tacked up where the light is good. There is no better sighting point than a small hand-mirror reflecting sunlight from the top of a stake that has been set to hold the position. If the paper sighting point is placed as much as one-fourth mile distant all necessary offsets may be provided by trimming as follows: width between the vertical edges to be double the right-angle offset of the reflector axis counting from the latitude axis; the lower right-and-left corners to be cut off for several inches on an angle from the vertical equal to the latitude of the station. Observe on the vertical edges for tests in the 0° latitude settings; on the slanting edges when the solar telescope is set in the latitude of the station.

(a) The vertical angle counts from the H.I. of the reflector.

(b) To set the correct north declination for the pick-up of the sighting point, solar unit, reflected image, when clamped in the latitude of the station, use the equation:

$$\sin \delta = \sin \phi \sin v$$

(c) To ascertain the horizontal angle, counting from the sighting point, that is to be turned in the tests of the declination arc, more than 90° for north declination, less than 90° for south declination, employ the equation:

$$\cos A = \frac{\sin \delta}{\cos v}$$

The purposes and the order of the tests, and in most cases the principles that are involved, have already been set out, included in (1) primary field tests, solar unit in good order; and (2) the general adjustments, solar diagram method, including the alternatives, both with and without the striding levels. These should be understood in principle. The explanations that follow are explicit to the extent that the prime vertical method gives a different approach to the problem.

(1) *The equatorial wires, for parallel to axis of reflector.* Start with the solar telescope clamped in the latitude of the station; the main telescope set on the sighting point, plate reading 0°, reflector in the direction of the sighting point; and a north declination set to the value: $\sin \delta = \sin \phi \sin v$; then turn the transit 90° to the right or left. Pick up the image of the sighting point by turning the solar telescope in hour angle; use the transit lower tangent motion to bring the central equatorial wire onto the image of the sighting point. Then turn the solar telescope in hour angle. The equatorial wire should follow the image of the sighting point across the field. This is the equivalent of test (1) of the general adjustments.

(2) *Collimation.* Make a direct sighting of the solar telescope on the sighting point; use the transit tangent motion for horizontal movement, the latitude tangent motion for movement in vertical angle. The test and adjustment then become the equivalent of test (2) of the general adjustments.

When the collimation is nearing close adjustment, complete the check by moving over to an outside equatorial wire. Use the transit tangent motion; set the equatorial wires on vertical, one outside wire on the sighting point. In this position the collimation test should be made by the reversal of one outside equatorial wire into the position of the other.

(3) *The polar axis.* Proceed as explained for test (3) of the general adjustments when using the solar diagram. Make the tests with the main telescope set on the sighting point, and direct sights through the solar telescope. The need for an allowance for the offset between the two telescopes depends upon the distance to the sighting point; it may be disregarded if more than one-half mile. In the endeavor to make allowance for an offset, much depends upon the sharpness of the image, the light, and the quality of the solar telescope for optical performance. A low vertical angle to the sighting point is preferred for this adjustment, but any vertical angle up to 20° is fully compensated in the steps that follow. Complete the first and second adjustments as previously explained when using the solar diagram. These two steps will bring the line of sight of the solar telescope into normal with the latitude axis, and the two telescopes substantially parallel at horizontal.

The next step is to check carefully for parallelism at horizontal, and to test (5) the reading of the declination arc in true 0° position.

Set and clamp at 0° latitude, and declination arc at or near 0°. Set the horizontal plate to read 0°, the main telescope on the sighting point, the reflector toward the sighting point. Then turn the transit 90° to the left; the solar in hour angle to late p.m. position. Pick up the reflected image of the sighting point; set the central equatorial wire on the sighting point by the declination tangent motion. Now reverse the transit, oriented 90° to the right of the sighting point; turn the solar telescope in hour angle to early a.m. position. Again pick up the image of the sighting point. Note the position of the central equatorial wire; if not in coincidence make the correction *half* with the declination tangent motion, *half* with the lower tangent motion of the transit. Repeat the reversals, and the half-and-half corrections until there is coincidence in both a.m. and p.m. positions. *The reading of the declination arc will give the index error, if any, in the setting of the vernier for zero declination.*

Also, now turn back to 0° horizontal plate reading. Observe the sighting point with the main telescope. *The discrepancy here, if any, is the error in parallelism at horizontal.* This shows what final "touch up", if any, may be required at the foot post that controls the pointing at horizontal sighting. If small, as it should be if the direct sighting tests were successfully executed, proceed with the final test for parallelism before changing the adjustment.

Clamp and set the solar telescope in the latitude of the station; then start with the main telescope set on the sighting point, plate reading 0°, reflector in the direction of the sighting point, and declination arc set to the value: $\sin \delta = \sin \phi \sin v$. Then turn the transit 90° to the left. Pick up the image of the sighting point by turning the solar telescope in hour angle; use the tangent motion of the declination arc to bring the central equatorial wire onto the image of the sighting point. Now reverse the transit, oriented 90° to the right of the sighting point; turn the solar telescope in hour angle, and again pick up the image of the sighting point. Note the position of the central equatorial wire; if not in coincidence make the correction *half* with the declination tangent motion, *half* with the lower tangent motion of the transit. Repeat the reversals, and the half-and-half corrections, until there is coincidence in both a.m. and p.m. positions. Now turn back to 0° horizontal plate reading. Observe the sighting point with the *main* telescope. *The discrepancy, if any, is the error in parallelism when set in the latitude of the station.*

If the parallelism is good when set in the latitude of the station it is better to let well-enough alone, i.e., no further touch-up adjustment is required. If not quite good, the previous test for parallelism at horizontal will show whether the final touch up should be made at the foot post that controls *the pointing at horizontal sighting,* or if the improvement is required at the foot post which controls *the axis of the latitude arc for horizontal.*

It is believed that this prime vertical method affords the most rigid test and adjustment of *the polar axis* that can be applied.

(4) *The latitude vernier.* The test for the reading of the vernier in true position of zero latitude may be made by direct sighting, first ascertaining a sighting point (or line) in the true horizontal plane of the solar telescope. This is the equivalent of test (4) of the general adjustments. Note also, that the primary field test (3) is made to secure an *instrumental latitude* at the station, which gives the value to be employed in solar orientation.

(5) *The declination vernier.* Note that in the adjustment (3) for the rigid test of the polar axis, one step required and gave an exact determination of the index error or setting of the vernier *for zero declination.* Note also, that the field test (2), preliminary to the test for orientation, is made to ascertain the index correction, if any, in that position of the arc for the period when the instrument is to be used. In field practice this is combined with the test for instrumental latitude. The test of the declination arc in the appropriate order of sequence is called the "prenoon test".

Begin by making a calculation of the sun's declination, for the apparent noon of the date, refraction applied. Then compute the horizontal angle A that is to be employed in making the reversals in this test, using the equation: $\cos A = \frac{\sin \delta}{\cos v}$; in this, "$\delta$" is the calculated noon declination; A will exceed 90° for north declinations; less than 90° for south declinations.

Start the test with the main telescope on the sighting point, plate reading at 0°, reflector in the direction of the sighting point. On the solar unit, set and clamped in 0° latitude; declination set at or near the desired noon value. On the first check, turn the transit to the left in the amount of the computed horizontal angle A. Turn the solar telescope in hour angle to late p.m., then pick up the image of the sighting point, set the central equatorial wire exactly on the image of the sighting point by the declination tangent motion. Now orient the transit to the right of the sighting point on the horizontal angle A; turn the the solar telescope to the early a.m. position. Pick up the image of the sighting point; note the central equatorial wire; if not in coincidence make the correction *half* with the declination tangent motion, *half* with the lower tangent motion of the transit. Repeat the reversals, and the half-and-half corrections until there is coincidence in both a.m. and p.m. positions. Now read the declination arc carefully. *This is the right setting of the declination arc for the noon determination of the instrumental latitude.* The discrepancy, if any, between this reading and the value of the declination as computed is the *exact index error for use in that part of the arc.*

(6) *The hour circle.* This is the same test as in the general adjustment (6) when made without the use of the solar diagram. Observe the watch reading and correction in apparent time at the meridian passage of the sun, for comparison with the reading of the hour circle. An altitude observation on the sun for apparent time may be substituted.

Summary List of Adjustments and Tests for the Transit and Solar Unit:

TRANSIT

Principal Adjustments and Tests

Plate levels
Cross wires, horizontal and vertical
Collimation
Horizontal axis
Horizontal sighting {single bubble / reversion bubble}
Fitting of vernier, vertical circle
Zero of vernier at two positions of vertical circle
Vert. ang. readings at + 40° and − 40°
Stadia ratio
Needle: pivot, magnetism, and balance

Tests for Repairs and Reconditioning

Centers
Focusing movements
Collimation, both long and short focus
Pivots and bearings
Readings, A and B verniers, at intervals of 30°
Repetition of angles, at 30°, 60°, and 90°
Reading of graduations, both circles and verniers (condition)
Horizontal and vertical clamps and tangent motions (condition)
Leveling screws (condition)
Clean and lubricate (condition)

SOLAR UNIT

Principal Adjustments and Tests

Equatorial wires, parallel to axis of mirror
Collimation
Spacing of equatorial wires
Line of sight, right angle to latitude axis
Latitude axis horizontal
Parallel sighting at horizontal
Parallel sighting at 40° N.
Zero, latitude vernier
Reading of latitude arc at 40° N.
Zero, declination vernier
Reading of declination arc, noon test, latitude known
Azimuth tests: a. m. and p. m.

Tests for Repairs and Reconditioning

Fitting of telescope in collar bearings
Focusing movements
True image, direct sighting
True image, reflected
Fitting of axis of mirror
Fitting of latitude arc, vernier, clamp, and tangent motion
Fitting of declination arc, vernier, clamp, and tangent motion
Reading of graduations, both arcs and verniers (condition)
Reading of decl. arc at 15° N. and 15° S.
Reading of decl. arc on 30° true hor. ang.
Reading of hour circle